Antepartum measurement of electromechanical time intervals using ultrasound

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Introduction

To determine the fetal pre-ejection time period (PEP), 2 events have to be detected: the onset of ventricular depolarisation and the moment of opening of the semilunar valves (AO). The abdominal fetal ECG (FECG) and continuous Doppler ultrasound (US) are most often used for this purpose during the antepartum period. Manual measurement of the PEP (1,2,3) from an oscilloscope screen or from a paper registration is in most cases not accurate enough. The low signal to noise ratio hinders identification of the QRS onset (Q_O). Another method uses the position of the fetal R wave and determines Q_O by employing a constant time shift (4). However, in different registrations this time difference is not constant. So for the detection of Q_O coherent averaging of fetal complexes is necessary in most cases (5).

Signal processing

In our clinical studies of the fetal cardiac intervals we made simultaneous registrations of the abdominal FECG and the Doppler signal (Sonicaid) on FM analog magnetic tape. The signals are stored in a computer system after the Doppler signal is successively high-pass filtered (750 Hz), rectified and low-pass filtered (250 Hz) to determine its envelope (fig. 1). Both FECG and the envelope of the Doppler signal are digitized with a sample frequency of 500 Hz. Also a fetal R-top trigger obtained from a fetal monitor (Corometrics) is stored in the computer system.

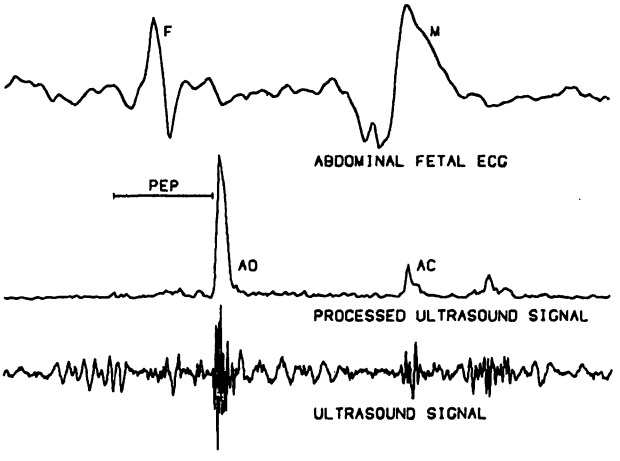

Fig. 1. Registration of the abdominal fetal ECG (upper tracing), Doppler ultrasound signal (lower tracing) and the pocessed ultrasound signal (middle tracing).

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To start the analysis the approximate position of 2 successive fetal QRS complexes and the moment of opening of the semilunar valves are manually indicated. With an iterative procedure, using the shape and the repetative nature of the QRS complexes, a template is formed consisting of an average of 10 fetal complexes. A cross-correlation function between this template and each fetal QRS complex is calculated. The position of maximum correlation is used as a fiducial point for that complex. A final average is obtained by averaging all complexes around the determined fiducial points (fig. 2). A second order derivative is used to determine Q_0 of the averaged QRS complex and likewise to determine the beginning of AO in the Doppler signal. The PEP is then calculated on a beat-to-beat basis using the determined difference between the fiducial point and Q_0.

The complete analysis is summarized for each registration on a A4 sheet and used to check the validity of the computational procedure.

In a study of 377 registrations of 2 min each we calculated the quartile range (QR) of the variation of the PEP. This includes physiological and methodological variation. The mean QR was 5 ms and in 76 registrations the QR was less than 2.5 ms.

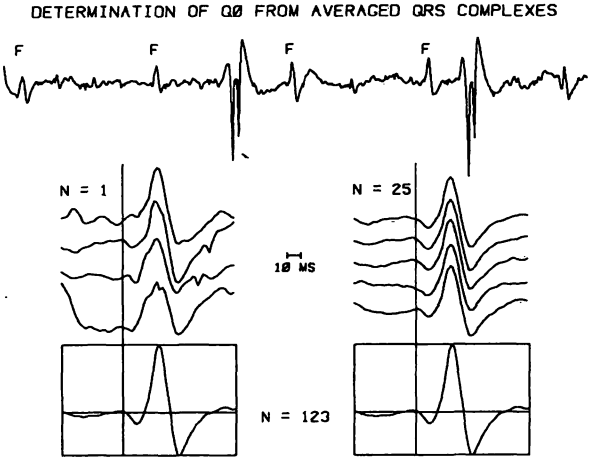

Fig. 2. Example of the use of an averaged QRS complex (bottom left) to determine the Q_0 in individual complexes. The 4 QRS complexes are shifted to a position of maximum cross-correlation with the averaged complex. Q_0 is indicated by a vertical line.

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